The CubeSat Infrared Atmospheric Sounder (CIRAS) Reducing the cost of future A-train-like measurements

A-Train Symposium, Session 6 - Special Session

Thursday, April 20, 2017

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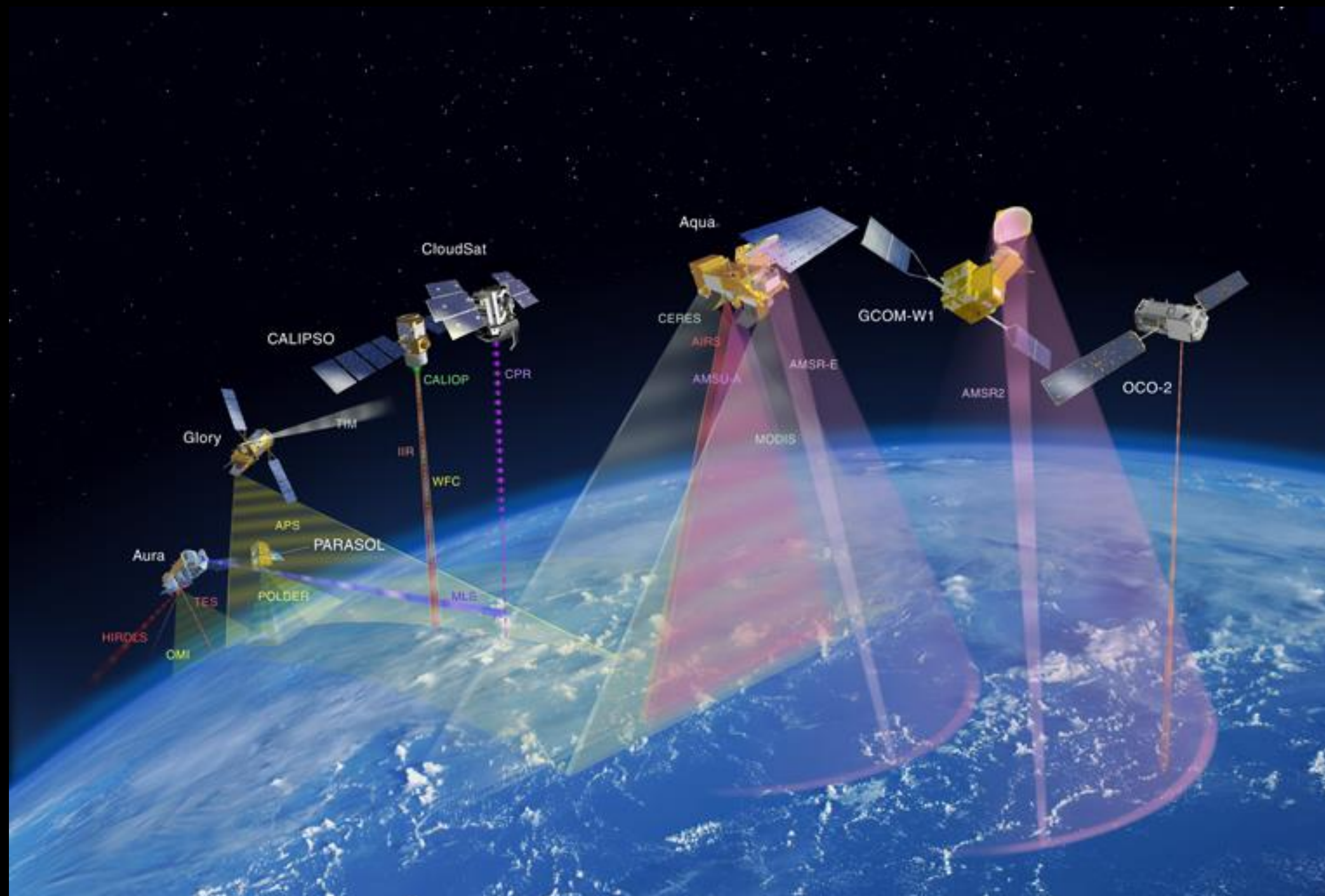
Aqua Launched May 4, 2002 from Vandenberg Air Force Base

Aqua was first in the "A-Train"

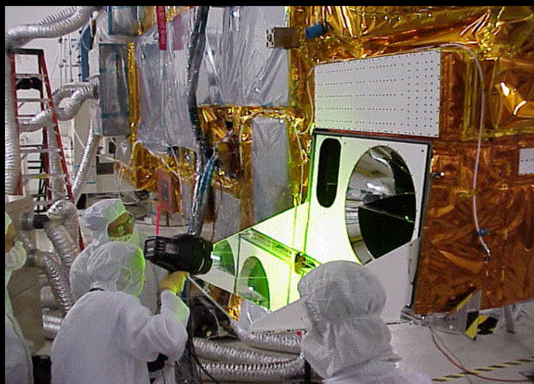
Aqua Launched On a Delta 2



The Aqua Spacecraft

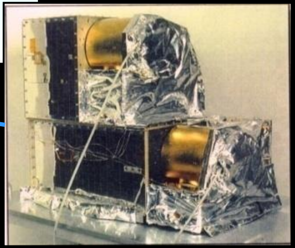
Launched May 4, 2002

Advanced Microwave Scanning Radiometer (AMSR-E)
MSFC/JAXA



Moderate Resolution Imaging Spectroradiometer (MODIS)
GSFC/Raytheon

Advanced Microwave Sounding Units (AMSU-A/B)
JPL/Aerojet



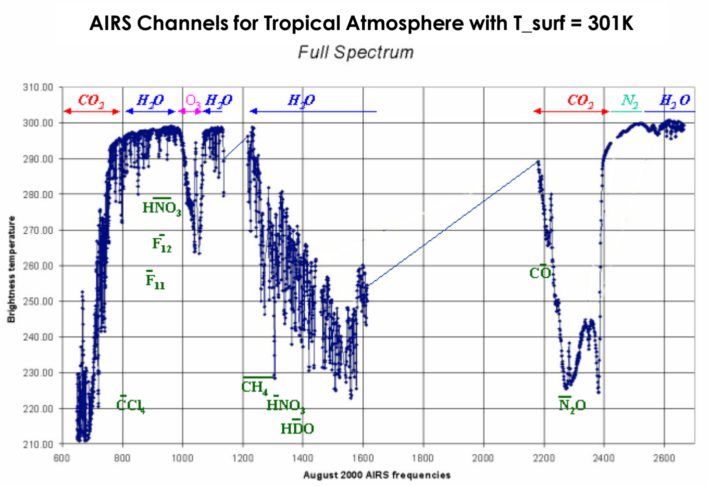
Humidity Sounder from Brazil (HSB)
JPL/Aerojet

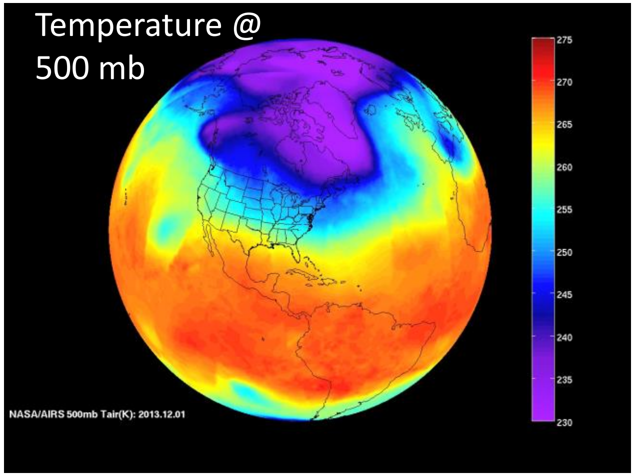
Atmospheric Infrared Sounder (AIRS)
JPL/BAE SYSTEMS

AQUA Spacecraft
GSFC/NGST

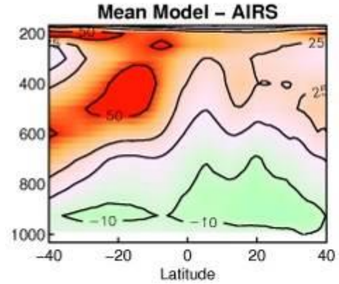
Clouds and Earth Radiant Energy System (CERES)
LaRC/NGST

AIRS Support Weather Forecasting and Climate Science



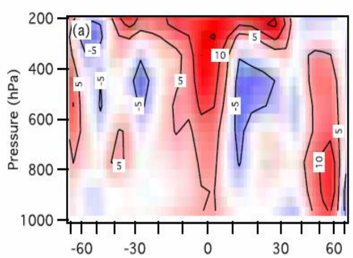


Water Vapor Climatology
(Pierce, Scripps, 2006)



AIRS has high impact to operational forecast

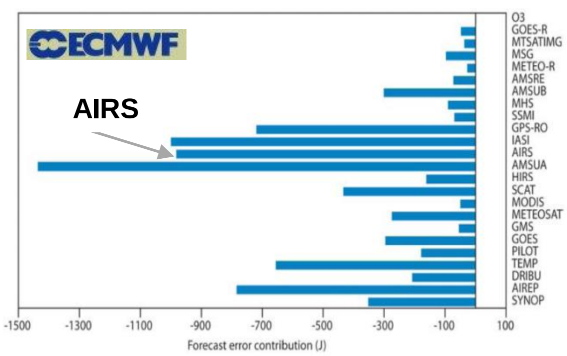
Water Vapor Feedback
(Dessler, Texas A&M, 2008)

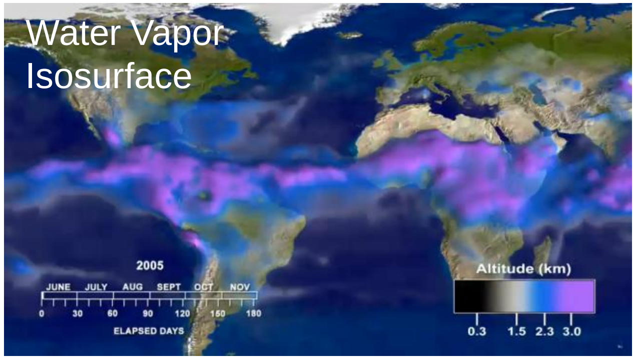


JPL/GSFC

NOAA
NESDIS/NCEP

JCSD

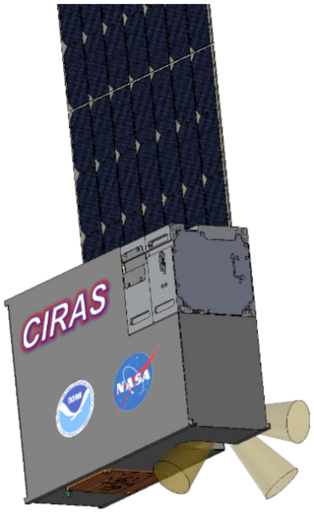




AIRS data products to be continued with the Crosstrack Infrared Sounder (CrIS) on JPSS into the late 2030’s

CubeSat Infrared Atmospheric Sounder (CIRAS) Mission Overview

- Mission Objectives
  - In-Space Technology demonstration for key infrared subsystems: HOT-BIRD IR Detectors, Grism Spectrometer, Black Silicon Blackbody
  - Demonstration of Mid-wavelength Infrared (MWIR) temperature and water vapor sounding. Comparable to AIRS/CrIS in the lower troposphere.
  - All technologies will be advanced to TRL 7 at the end of experiment
- Implementation Summary
  - JPL Lead + HOTBIRD + Grism + Black Si, Ball Optics, IR Cameras Camera, Blue Canyon Technologies (BCT) Spacecraft
  - 6U CubeSat (approx. 30 x 20 x 10 cm, <14 kg)
  - LEO Sun Synchronous Morning Orbit (450 km – 600km)
  - Minimum Mission Duration: 3 months



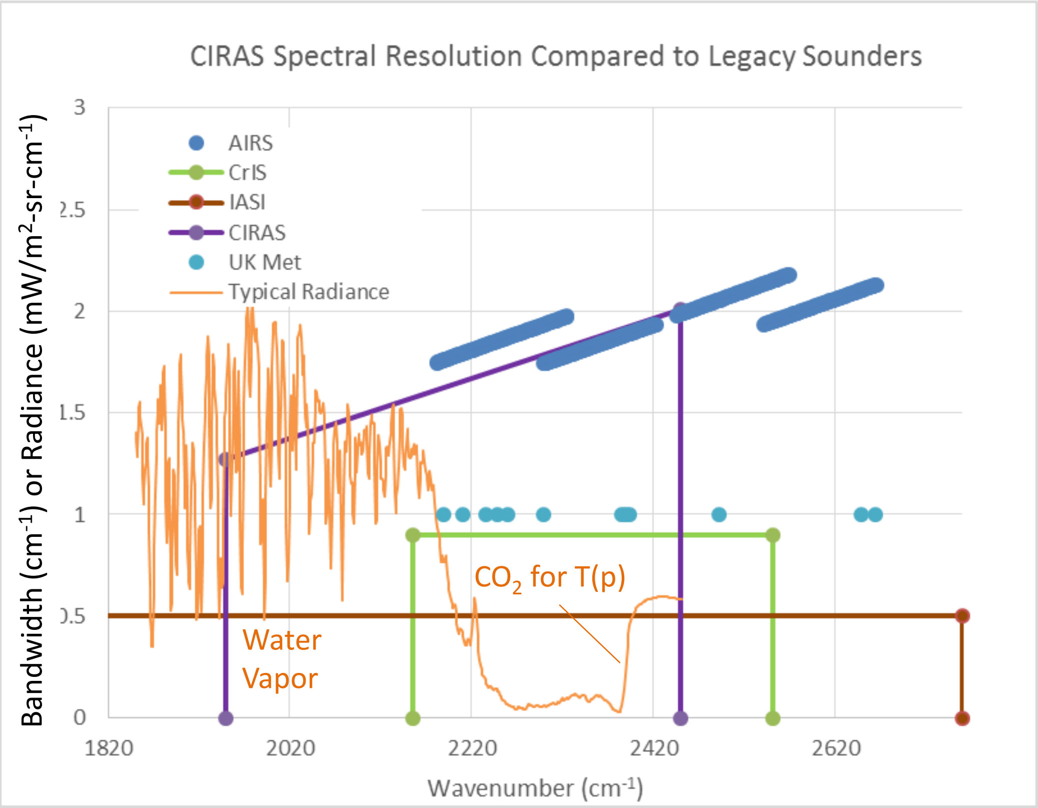
- Programmatic Summary
  - Sponsored by NASA Earth Science Technology Office (ESTO) In-flight Validation of Earth Science Technologies (InVEST) Program, Awarded 2015
  - Design performed in collaboration with the EON-IR Study sponsored by the NOAA Office of Projects, Planning, and Analysis (OPPA)
  - Selected on 2/18/16 for a launch opportunity by the NASA CubeSat Launch Initiative .
  - Interim Review 1 on February 10, 2017
  - Launch no earlier than January 2019

CIRAS spectral performance comparable to AIRS in the MWIR

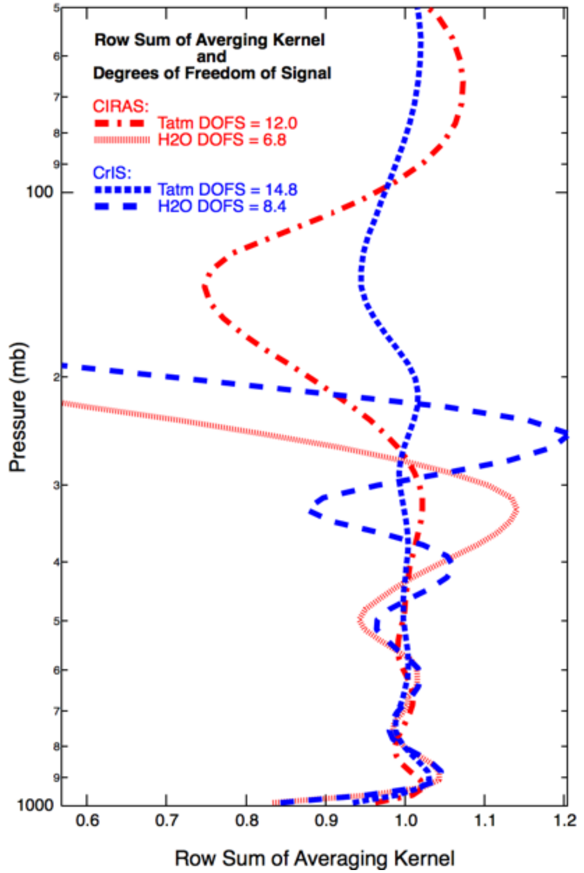
CIRAS Spectral like AIRS but Extends into the Water Band

1950 cm^{-1} – 2450 cm^{-1}

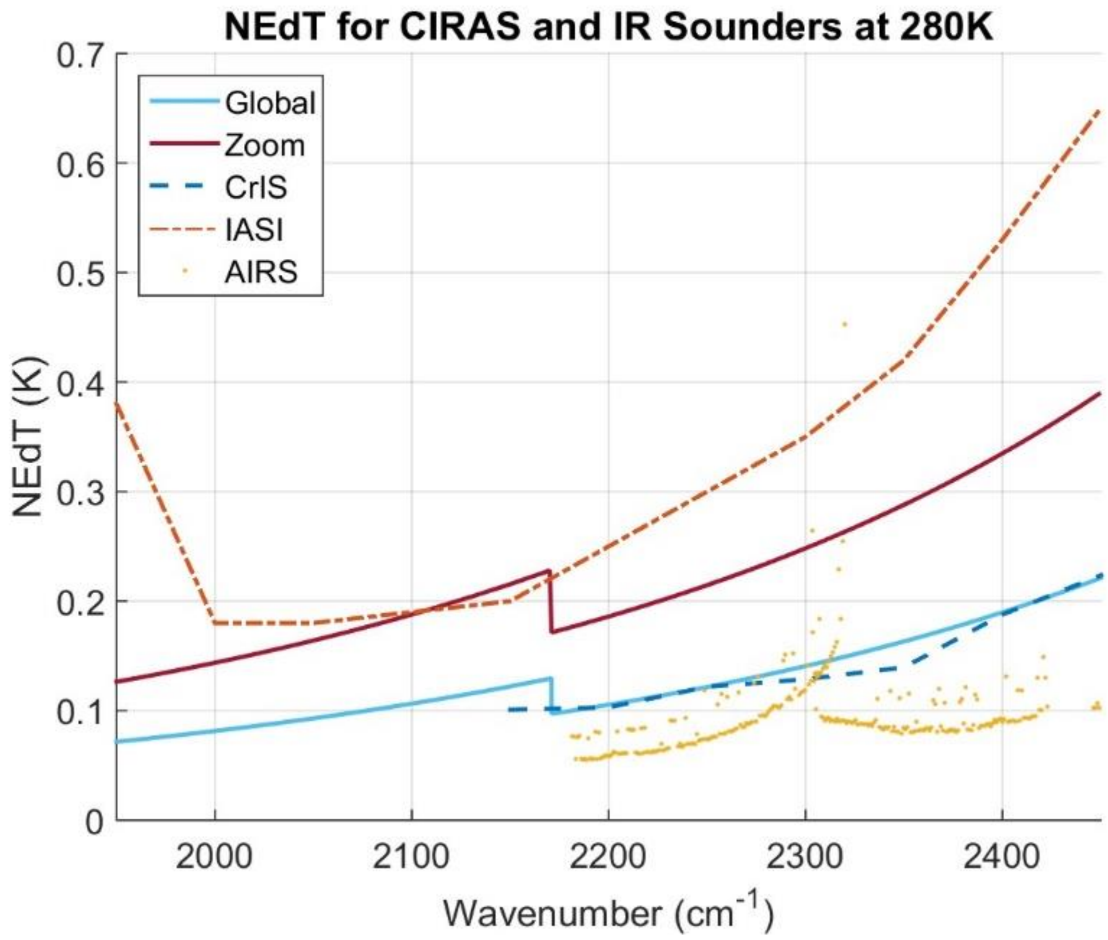
Δv = 1.2-2.0 cm^{-1} , N_{ch} = 625



CIRAS Information Content Extends from the Surface to 300 mb



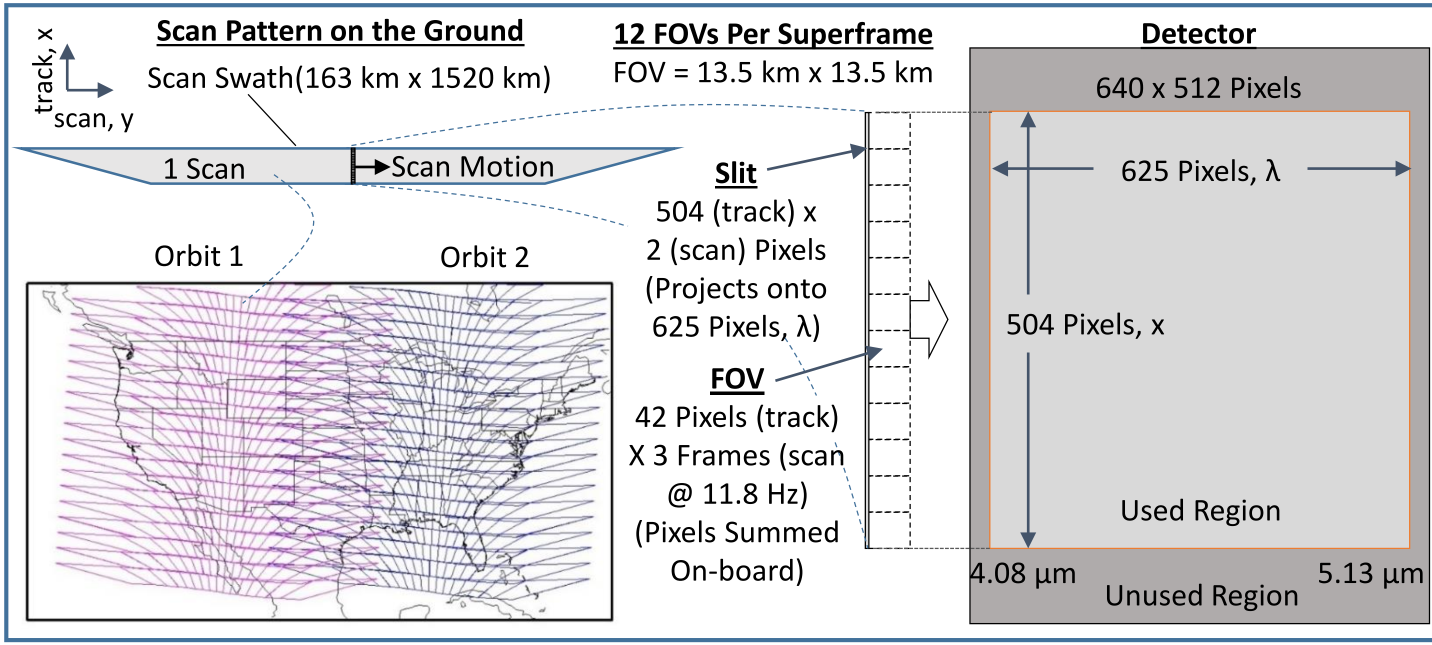
CIRAS Noise Equivalent Differential Temperature (NEdT) Comparable to Legacy Sounders



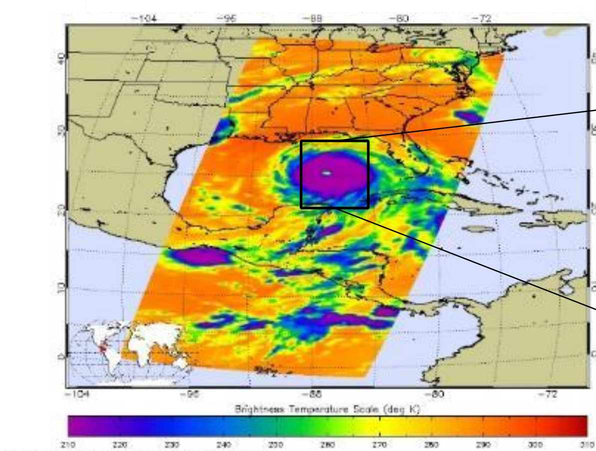
CIRAS spatial resolution comparable to AIRS, CrIS + Zoom

- **Programmable Pixel Binning and Scan Rate Allow Global and Zoom Modes**

CIRAS Binning Scheme (600 km Orbit)

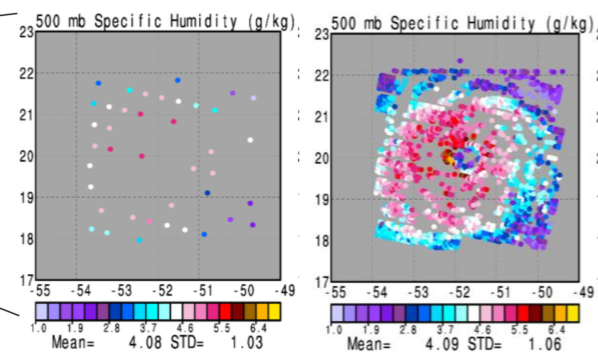


AIRS Global Mode



Simulated Sounder Yield

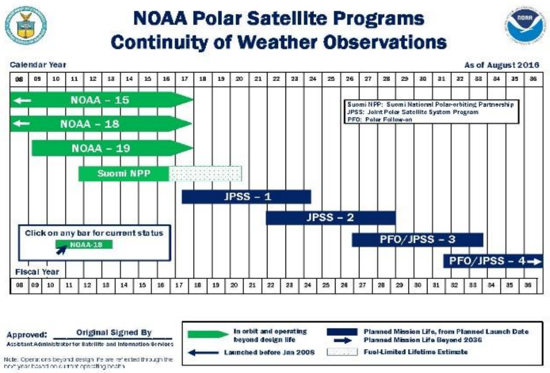
Global Mode 13.5 km GSD | **Zoom Mode 3 km GSD**

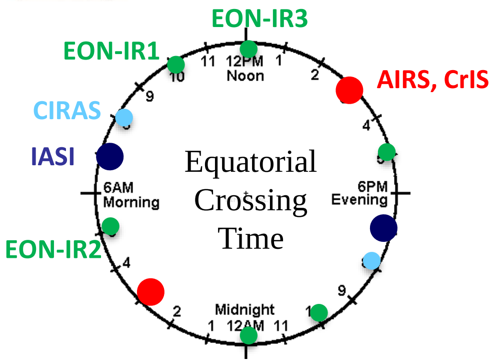


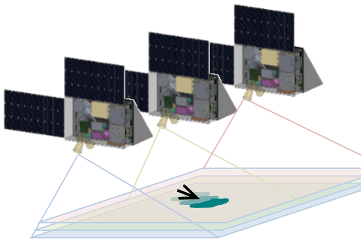
Susskind (GSFC)

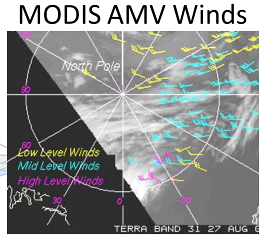
CIRAS Future Mission Concepts

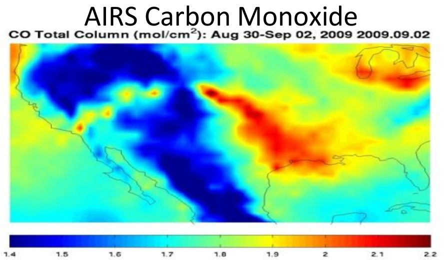
- **Gap Mitigation**:
  - Support the NOAA Joint Polar Satellite System (JPSS) project as a gap mitigation of infrared sounding in the event of a loss of the Cross-track Infrared Sounder (CrIS) instrument.
  - NOAA has identified the Earth Observation Nanosatellite-Infrared (EON-IR) as a potentially valuable instrument for gap mitigation
  - CIRAS is a technology pathfinder for EON-IR
- **Improved Timeliness**:
  - Low cost of CIRAS lends itself to placement in orbits to complement existing sounders and improve revisit time
  - This application could be used to improve Numerical Weather Prediction worldwide, or to study the diurnal properties of hydro-thermodynamic processes in the lower troposphere.
- **3D AMV Winds**:
  - Each CIRAS sounder provides imagery of water vapor in 3D since each horizontal pixel contains a vertical sounding profile.
  - 3 CIRAS instruments flown in formation and separated in time by 15 min – 1 hr would allow measurement of the data needed to produce 3D Atmospheric Motion Vector (AMV) winds
- **AIRS Pollution Studies**
  - The CIRAS band from 1950-2450 cm^{-1} can measure lower tropospheric Carbon Monoxide (CO)





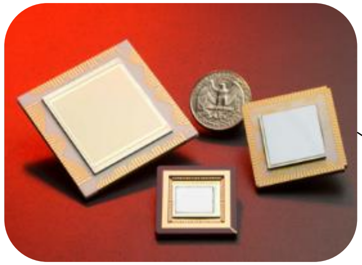






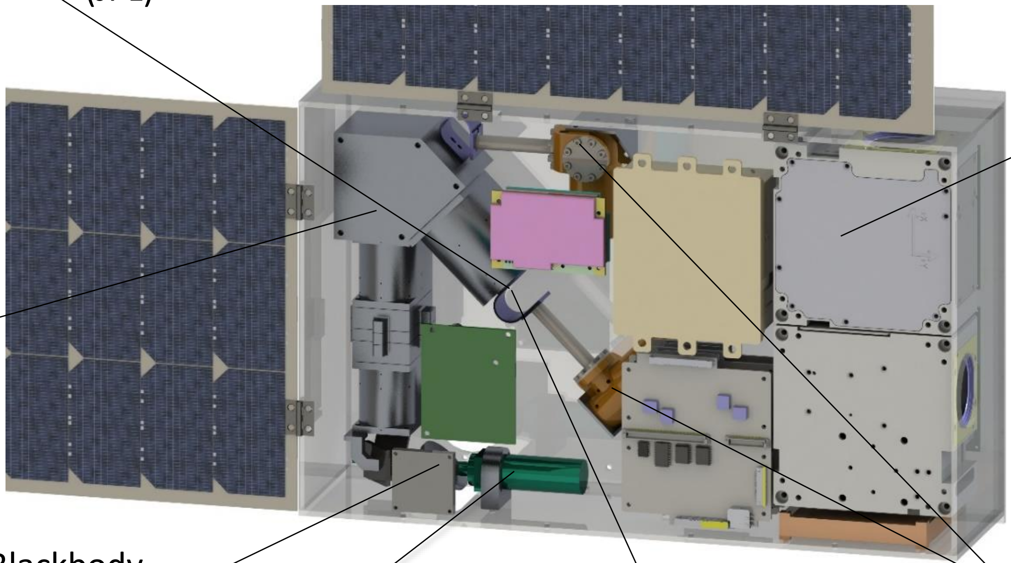
CIRAS Key Technologies

Size	6U Cubesat
Mass	14 kg
Power	37.5W
Data Rate	0.3 Mbps

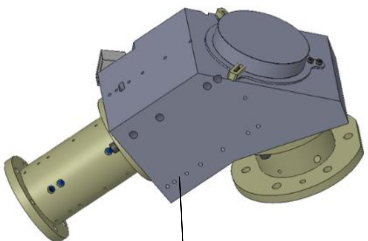


Detectors and FPA HOTBIRD (JPL)

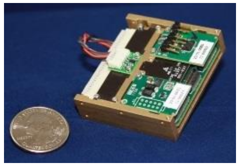
Spacecraft (Blue Canyon Technologies)



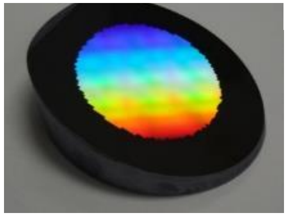
Optics Assembly Telescope/MGS (Ball)



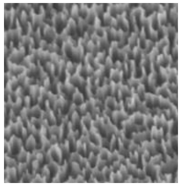
Camera Electronics (IR Cameras)



Immersion Grating (JPL)



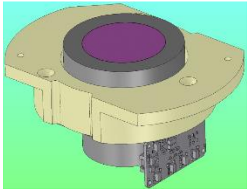
Blackbody Assembly Black Silicon



JPL MDL Technologies

Scan Mirror Assy Stepper Motor + Electronics (Lin Eng)

Dewar (IDCA) (IR Cameras)



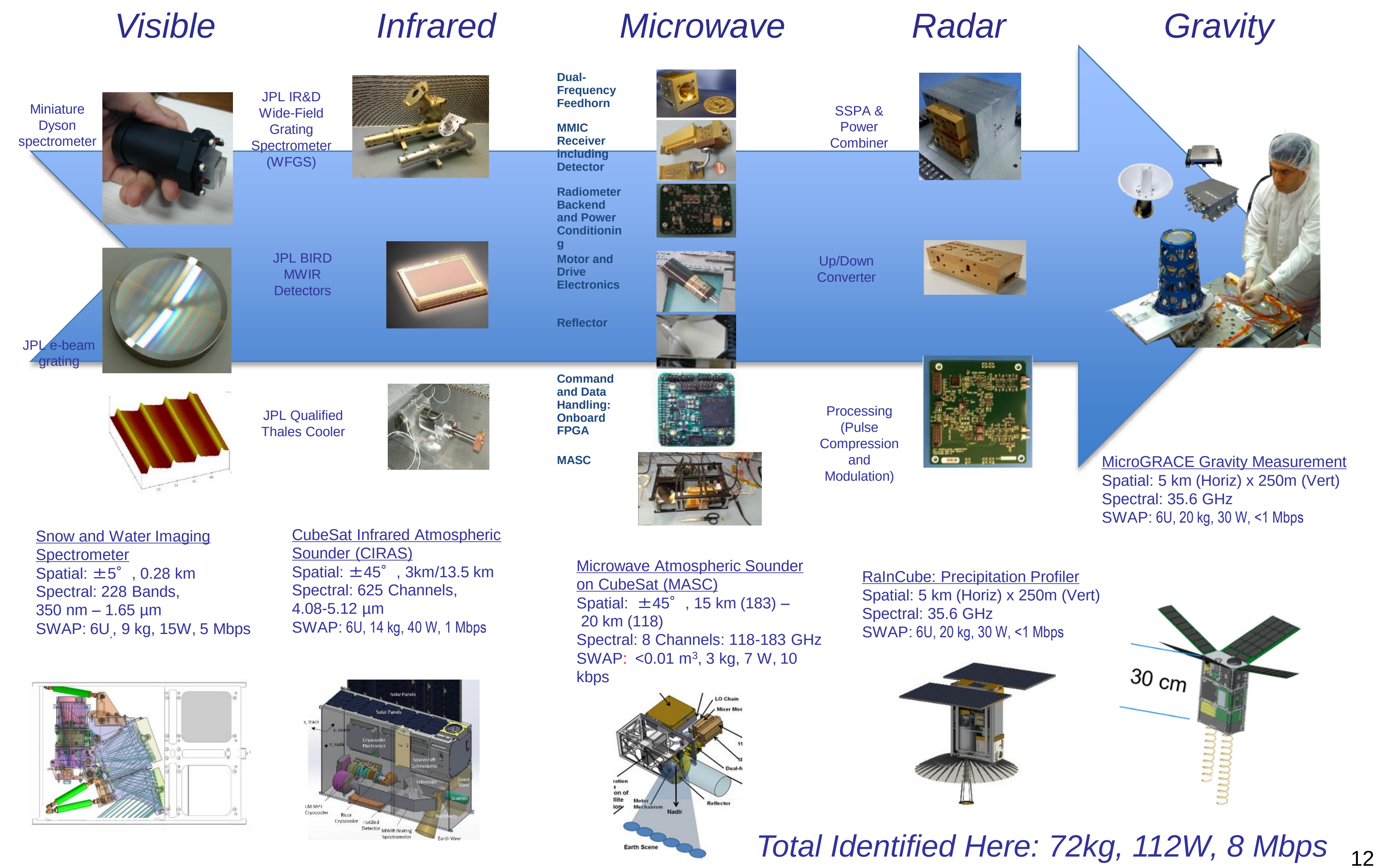
Cryocoolers + Electronics (Ricor K508)

Payload Electronics (TEMPEST-D JPL)

Questions remain and work to be done

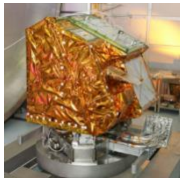
- **Questions remain:**
  - Is the impact of CIRAS sufficiently positive to make it worth the cost to NWP centers?
  - Is the information content in the MWIR band sufficient to capture the key IR sounder climate variables: T(p), q(p), clouds, trace gases?
  - Are the radiances of sufficient accuracy and stability to complement the climate record?
  - Can Winds be derived from a constellation of CIRAS-Like CubeSats
- **Work to be done:**
  - Successful implementation of CIRAS will help answer some of these questions.
  - Requires support from the IR sounding community, NASA, NOAA and NWP centers worldwide is essential
    - Additional technology demonstration to support operational implementation of CIRAS (towards an EON-IR). Thermal control, extended life, higher duty cycle, etc.
    - Cross-calibration demonstration with CIRAS, AIRS, IASI, CrIS
    - Radiative transfer improvement in the MWIR
    - Data assimilation studies (e.g. OSSEs)
    - Mission planning and architecture studies (e.g Orbits, Sensor Web)
    - Sensor simulation studies: Effects of sensor performance on measurement objectives. (NEdT, Spectral Resolution, Spatial Resolution, etc.)
    - International participation will promote development of a low cost constellation

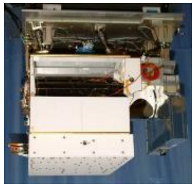
Next Generation Technology at JPL Enables Future A-Train-like measurements in CubeSats



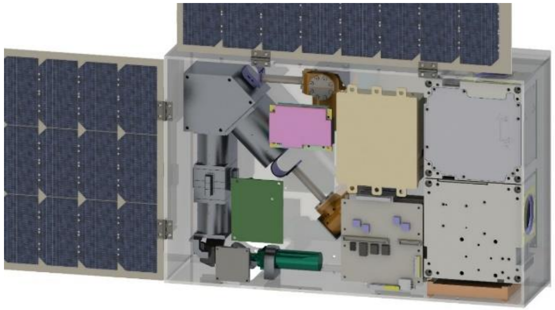
Summary and Conclusions

- **Legacy IR Sounding**
  - Hyperspectral Infrared atmospheric sounders measure the upwelling Earth radiances with high spectral and radiometric resolution, precision and accuracy
  - IR Sounder data show high impact to operational forecast and support premier atmospheric process and climate science
  - The future of IR Sounders is assured with AIRS, CrIS and IASI

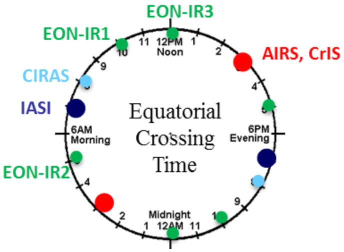




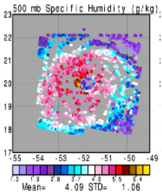
- **The CubeSat Infrared Atmospheric Sounder (CIRAS)**
  - Tech demo under development at JPL with Ball, IR Cameras, and BCT
  - Sponsored by the NASA InVEST program
  - Scheduled for launch in early 2019 timeframe



- **CIRAS is cheap. How can we make use of this asset?**
  - Gap mitigation, additional orbits, 3-satellite constellation for AMV Winds
  - Zoom mode (3km) will help focus on critical areas



- **CIRAS is highly synergistic**
  - Existing IR Sounders (AIRS, CrIS, IASI)
  - Microwave CubeSat sounders (e.g. MicroMAS, TEMPEST-D)
  - Other A-Train Like Measurements with CubeSats: Imagers, Radar



- **Technology development needed**
  - MWIR RTAs, MWIR Data Assimilation, LWIR Detector Arrays, Micro Cryocoolers